

HST WFPC2 Imaging of Shocks in Superbubbles

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ABSTRACT

Bright X-ray emission has been detected in superbubbles in the Large Magellanic Cloud (LMC), and it is suggested that supernova remnants (SNRs) near the inner shell walls are responsible for this X-ray emission. To identify SNR shocks in superbubble interiors, we have obtained *HST* WFPC2 emission-line images of the X-ray-bright superbubbles DEM L 152 and DEM L 192 and the X-ray-dim superbubble DEM L 106. We use these images to examine the shell morphology and [S II]/H α ratio variations in detail.

Of these three superbubbles, DEM L 152 has the highest X-ray surface brightness, the most filamentary nebular morphology, the largest expansion velocity (~ 40 km s $^{-1}$), and the highest [S II]/H α ratio (0.4–0.6). Its [S II]/H α ratio increases outwards and peaks in sharp filaments along the periphery. DEM L 192 has a moderate X-ray surface brightness, a complex but not filamentary morphology, a moderate expansion velocity (35 km s $^{-1}$), and a low [S II]/H α ratio (~ 0.15). DEM L 106 is not detected in X-rays. Its shell structure is amorphous and has embedded dusty features; its expansion velocity is < 10 km s $^{-1}$.

None of the three superbubbles show morphological features in the shell interior that can be identified as directly associated with SNR shocks, indicating that the SNR shocks have not encountered very dense material. We find that the [S II]/H α ratios of X-ray-bright superbubbles are strongly dependent on the UV radiation field of the encompassed OB associations. Therefore, a tight correlation between [S II]/H α ratio and X-ray surface brightness in superbubbles should not exist. We also find that the filamentary morphologies of superbubbles are associated with large expansion velocities and bright X-ray emission.

Subject headings: ISM: bubbles – ISM: H II regions – ISM: individual (DEM L 106, DEM L 152, DEM L 192) – ISM: kinematics and dynamics – Magellanic Clouds

1. Introduction: SNRs in Superbubbles

Bright X-ray emission has been detected in superbubbles in the Large Magellanic Cloud (LMC). As their X-ray luminosities are much higher than those expected in superbubble models (e.g., Weaver et al. 1977), it is suggested that supernova remnants (SNRs) near the inner shell walls are responsible for the X-ray emission (Chu & Mac Low 1990; Wang & Helfand 1991).

SNRs in superbubbles cannot be confirmed easily by the conventional diagnostics of nonthermal radio emission and a high $[\text{S II}]/\text{H}\alpha$ line ratio. The radio and optical emission of SNRs in superbubbles is weak because the SNRs interact with a low-density medium. Their weak nonthermal radio emission is further drowned out by thermal emission from bright background H II regions. The $[\text{S II}]$ line strength is weakened because sulfur may be photoionized to higher ionization stages by the UV radiation from the OB associations in the superbubble. Therefore, the conventional methods for identifying SNRs are ineffective for SNRs in superbubbles.

Alternative methods have been used to search for evidence of SNRs in X-ray-bright superbubbles. One of these attempts has used high-dispersion spectroscopic observations of the $\text{H}\alpha$ emission line to search for high-velocity ($\Delta V \geq 100 \text{ km s}^{-1}$) shocked gas in X-ray-bright superbubbles. The emission measures of the shocked gas, as derived from the X-ray surface brightness, are high, but high-velocity gas is not detected in the 4m echelle/CCD observations (Chu 1997). This negative result is consistent with the suggestion that the SNR shocks are interacting with the hot, low-density interior of the superbubble. The small recombination coefficient and large thermal width associated with the high temperatures in the post-shock gas prohibit the detection of high-velocity gas in the $\text{H}\alpha$ emission line profiles.

One other attempt to search for SNRs in superbubble interiors used the UV interstellar absorption line properties. If the SNR shocks are interacting mainly with the hot interior of a superbubble and have not yet reached the cold, dense shell wall, the high-ionization species

will exhibit different velocity profiles than the low-ionization species. The high-ionization species are expected to possess an additional shocked, high-velocity component. Chu et al. (1994) examined all available archival high-dispersion *International Ultraviolet Explorer* (*IUE*) spectra of targets in the LMC, and found promising diagnostics of SNR shocks only in the superbubble N51D (de Boer & Nash 1982) and the giant H II region 30 Doradus.

Thus, we need to find other diagnostics to confirm the existence of SNRs in superbubbles. As the interstellar medium is most likely clumpy, there might be dense cloudlets left in the superbubble interior. Small, shocked cloudlets ($\leq 1''$) cannot be resolved by ground-based telescopes, and hence would be difficult to identify. The Wide Field and Planetary Camera 2 (WFPC2) on board the *Hubble Space Telescope* (*HST*), being able to resolve features as small as $0''.2$, or 0.05 pc for a distance of 50 kpc to the LMC (Feast 1991), provides an opportunity to search for evidence of SNR shocks in superbubble interiors. Indeed, small shocked cloudlets have been successfully detected by *HST* WFPC2 images in the SNR N63A (Chu et al. 1999).

We have selected three superbubbles of different X-ray surface brightnesses for *HST* WFPC2 imaging: DEM L 106, DEM L 152, and DEM L 192 in the LMC (“DEM” – Davies, Elliott, & Meaburn 1976). DEM L 152, part of N44 (“N” – Henize 1956), is the brightest X-ray superbubble in the LMC, with an X-ray luminosity $L_X \sim \text{a few} \times 10^{36} \text{ ergs s}^{-1}$ in the 0.5–2.0 keV band (Chu et al. 1993). DEM L 192, also known as N51D, is of moderate X-ray surface brightness, with $L_X \sim \text{a few} \times 10^{35} \text{ ergs s}^{-1}$ in the 0.15–4.5 keV band (Chu & Mac Low 1990). DEM L 106, or N30C, has the lowest X-ray surface brightness and has not been detected by *Einstein* or *ROSAT*; the 3σ upper limit on its X-ray luminosity is $L_X \leq 10^{35} \text{ ergs s}^{-1}$ in the 0.1–2.4 keV band (Chu et al. 1995). These three superbubbles allow us to seek a possible relationship between the nebular morphology of the 10^4 K gas and the X-ray surface brightness of the 10^6 K gas, in order to determine how interior SNRs affect the physical properties of a superbubble.

This paper reports the WFPC2 images of these three superbubbles. In §2, we describe the observations and data reduction. In §3, we describe the morphologies of the superbubbles

and discuss the apparent relationship between their $H\alpha$ morphologies and X-ray surface brightnesses. We further compare these three superbubbles to other LMC fields of which archival *HST* WFPC2 $H\alpha$ images are available, and discuss whether the apparent relationship between $H\alpha$ morphology and X-ray surface brightness can be generalized. A summary of our conclusions is given in §4.

2. Observations and Data Reduction

HST WFPC2 CCD images of DEM L 106, DEM L 152, and DEM L 192 were taken between 1998 November and 1999 January for the Cycle 6 program 6698. The journal of observations is given in Table 1. Two filters were used, the $H\alpha$ filter (F656N) and the [S II] filter (F673N), so that we could search for small shocked features and further use the [S II]/ $H\alpha$ ratio to probe their nature. No [S II] images were taken for DEM L 106 because its surface brightness was low and its $H\alpha$ observations required an entire orbit. Figure 1 shows these WFPC2 $H\alpha$ images and their corresponding ground-based $H\alpha$ images.

The images were processed using the standard *HST* data pipeline and combined to remove cosmic rays. To extract fluxes from the $H\alpha$ and [S II] images, we have followed the procedures for narrow-band photometry¹. We first divide a combined image by its total exposure time to obtain a count-rate map, and multiple it by the parameter PHOTFLAM in the image header to convert from count rates to flux densities. We then use the task SYNPHOT in the STSDAS software package to determine filter widths, 28.3 Å for $H\alpha$ and 63.3 Å for [S II]. Finally, we multiply the flux densities by the corresponding filter widths to obtain fluxes.

The flux-calibrated [S II] images are divided by the flux-calibrated $H\alpha$ images to derive [S II]/ $H\alpha$ ratio maps. To suppress the large [S II]/ $H\alpha$ ratio fluctuations in faint (and hence noisy) regions, we have clipped pixels with fluxes less than 3σ above the sky background for

¹See http://www.stsci.edu/instruments/wfpc2/Wfpc2_faq/wfpc2_nrw_phot_faq.html at

both the $H\alpha$ and $[S\text{ II}]$ images of DEM L 152 and DEM L 192. The $[S\text{ II}]/H\alpha$ ratio maps of DEM L 152 and DEM L 192 are presented in Figure 2.

We have compared these $[S\text{ II}]/H\alpha$ ratios of DEM L 152 and DEM L 192 to those derived from long-slit, low-dispersion CCD spectra taken with the 1.5-m telescope and the 2D-Frutti spectra taken with the 1-m telescope at Cerro Tololo Inter-American Observatory (Kennicutt 2000). The two sets of observations were made at the same slit positions and with a $5''$ -wide slit. Spectra were extracted over slit lengths of $\sim 20''$ in order to obtain adequate S/N ratios. Two spectra were extracted for DEM L 152 and four for DEM L 192. The slit positions were recovered by matching the surface brightness profiles of the $H\alpha$ line along the slits to those of the WFPC2 $H\alpha$ images. Despite the coarse spatial resolution of the spectra, we find that the slit positions relative to the WFPC2 images can be determined to better than $1''$, as the WFPC2 surface brightness profiles change significantly with a shift larger than $1''$. The $[S\text{ II}]/H\alpha$ ratios derived from the CCD spectra agree with those derived from the 2D-Frutti spectra with a $\sim 20\%$ scatter. The $[S\text{ II}]/H\alpha$ ratios derived from the WFPC2 images are systematically higher than the spectroscopic values, 10% higher for DEM L 152 and 40% higher for DEM L 192. This discrepancy might be caused by diffuse continuum emission in the WFPC2 images. This discrepancy does not affect our evaluation of the $[S\text{ II}]/H\alpha$ variations within each superbubble.

3. Results and Discussions

The *HST* WFPC2 images allow us to examine the nebular morphologies and $[S\text{ II}]/H\alpha$ ratios at high spatial resolution. Note that the $[S\text{ II}]/H\alpha$ ratio, while often used as a shock indicator, is not uniquely related to the shock velocity. The $[S\text{ II}]/H\alpha$ ratio is high at both low shock velocities ($< 50 \text{ km s}^{-1}$) and high shock velocities ($> 100 \text{ km s}^{-1}$) (Shull & McKee 1979). Furthermore, the $[S\text{ II}]/H\alpha$ ratio is affected by the local UV radiation field. If early-type O stars exist in the vicinity, their UV radiation will ionize sulfur to S^{+2} and S^{+3} and weaken the $[S\text{ II}]/H\alpha$ ratio behind the shocks.

Below we describe the morphology and $[\text{S II}]/\text{H}\alpha$ ratios of each superbubble, and interpret the observations using our best knowledge of the expansion velocity and stellar content of the superbubble. The superbubbles are presented in the order of decreasing X-ray luminosity and surface brightness. Later, we discuss the relationship between the nebular morphology and the X-ray surface brightness, and suggest an interpretation.

3.1. DEM L 152 (N44)

Among the three superbubbles studied, DEM L 152 has the highest X-ray luminosity, $L_X = 1\text{--}35 \times 10^{36} \text{ ergs s}^{-1}$ in the 0.5–2.0 keV band (Chu et al. 1993; Magnier et al. 1996)², and the largest expansion velocity, $\sim 40 \text{ km s}^{-1}$ (Meaburn & Laspias 1991; Chu 1997). The X-ray emission from DEM L 152 extends from its interior to beyond the southern rim, suggesting a breakout in the superbubble (Chu et al. 1993). This breakout has been confirmed by velocity structures of the $\text{H}\alpha$ line and variations in the plasma temperature (Magnier et al. 1996).

As shown in Figure 1a, DEM L 152 has a very filamentary optical morphology. The WFPC2 field of view is centered near the breakout region. The WFPC2 $\text{H}\alpha$ image indeed shows an apparent gap in the southern rim at $5^{\text{h}}22^{\text{m}}33^{\text{s}}$, $-67^{\circ}58'12''$ (J2000). Most of the filaments are straight and narrow ($\sim 1''$ wide, $\sim 10\text{--}20''$ long), and are parallel to the direction of the outflow. The narrowest filaments have FWHM of $\sim 0''.5$, or 0.12 pc.

²The uncertainty in the X-ray luminosity is caused by the uncertainty in the spectral fits and a large absorption correction at this soft energy band. Chu et al. (1993) used only *ROSAT* PSPC observations for spectral fits, and found plasma temperatures of $1.5 - 3 \times 10^6 \text{ K}$ and absorption column densities of 10^{22} cm^{-2} . They derived an X-ray luminosity of $3 - 35 \times 10^{36} \text{ erg s}^{-1}$ in the 0.5–2.0 keV band. Magnier et al. (1996) used both *ROSAT* and *ASCA* observations for spectral fits and found a plasma temperature of $6 \times 10^6 \text{ K}$ and an absorption column density of 10^{21} cm^{-2} . Using the spectral fits from Magnier et al., we calculated an X-ray luminosity of $\sim 1 \times 10^{36} \text{ erg s}^{-1}$ in the 0.5–2.0 keV band.

The $[\text{S II}]/\text{H}\alpha$ ratio map of DEM L 152 (Figure 2a) shows that the $[\text{S II}]/\text{H}\alpha$ ratios of DEM L 152 are generally in the range of 0.4–0.6, which is higher than those of normal H II regions, but still lower than the values typically seen in SNRs, ≥ 0.7 . Systematic variations of the $[\text{S II}]/\text{H}\alpha$ ratios are seen. First, the superbubble shell shows lower $[\text{S II}]/\text{H}\alpha$ ratios, ~ 0.4 (light blue), along the inner edge, and higher $[\text{S II}]/\text{H}\alpha$ ratios, up to ~ 0.6 (yellow), along the outer edge. Second, the long filaments along the outflow direction have higher $[\text{S II}]/\text{H}\alpha$ ratios, ~ 0.5 (red to yellow).

The $[\text{S II}]/\text{H}\alpha$ ratios of DEM L 152 can be explained by the radiation field provided by the stars in the superbubble. Two OB associations have been identified in the vicinity of DEM L 152: LH47 in the superbubble’s interior and western rim, and LH48 in the compact H II region on the superbubble’s northern rim (Lucke & Hodge 1970; Chu & Mac Low 1990). The earliest-type stars, earlier than O6, are located in either LH48 or the western edge of LH47, both are inside dense H II regions. The stars that are projected in the central cavity of DEM L 152 are all of later types, such as late-O or early-B (Oey & Massey 1995). These relatively late early-type stars do not have a strong UV radiation field. The weakness of the UV radiation field is testified by the presence of a neutral H I shell exterior to the ionized gas shell of DEM L 152, indicating that the ionization front is trapped within the superbubble shell (Kim et al. 1998a). At the ionization front, sulfur is mostly singly ionized; therefore, the observed $[\text{S II}]/\text{H}\alpha$ ratios are high and peak at the outer edge of the ionized gas shell.

3.2. DEM L 192 (N51D)

N51D has a moderate X-ray luminosity, $L_X \sim 3 \times 10^{35}$ ergs s^{-1} in the 0.15–4.5 keV band; its X-ray emission is confined within the optical shell, with the brightest X-ray emission adjacent to the bright eastern rim (Chu & Mac Low 1990). The expansion velocity of DEM L 192 is moderate, $\sim 30\text{--}35$ km s^{-1} (Lasker 1980; Meaburn & Terrett 1980).

Our WFPC2 images of DEM L 192 are centered near the eastern rim, where the X-ray

emission peaks. Figure 1b shows that it has a complex but not filamentary optical morphology. The only sharp narrow feature occurs at the edge of the WF4 CCD, the western edge of the field of view. This sharp feature appears to be the ionized surface of a dense, irregular cloud.

As shown in Figure 2b, the $[\text{S II}]/\text{H}\alpha$ ratios in DEM L 192 are in the range of 0.1–0.25 (green – blue), much lower than those in DEM L 152. If the spectroscopically determined $[\text{S II}]/\text{H}\alpha$ ratios are used, the $[\text{S II}]/\text{H}\alpha$ ratios of DEM L 192 are 40% lower, and the difference between DEM L 192 and DEM L 152 is even larger. The sharp feature at the western edge has the highest $[\text{S II}]/\text{H}\alpha$ ratio, up to ~ 0.4 (blue to light blue). There is no systematic variation in the $[\text{S II}]/\text{H}\alpha$ ratio; for example, the $[\text{S II}]/\text{H}\alpha$ ratio is not correlated with the surface brightness.

The small $[\text{S II}]/\text{H}\alpha$ ratios within DEM L 192 can also be explained by the radiation field provided by the stars in the superbubble. Two OB associations are identified within the boundary of DEM L 192: LH54 in the central cavity and LH51 near the western rim (Lucke & Hodge 1970; Chu & Mac Low 1990). Our WFPC2 field of view is close to the OB association LH54, which contains an O4 III(f*) star and a WC5 star (Oey & Smedley 1998). The O4 III star, having an effective temperature of 48,180 K (Schaerer & de Koter 1997), is among the hottest stars and can easily ionize sulfur to S^{+2} , thus weakening the $[\text{S II}]$ emission and reducing the $[\text{S II}]/\text{H}\alpha$ ratios. Furthermore, no H I shell is detected exterior to the ionized shell of DEM L 192, indicating that the shell is optically thin (Kim et al. 1998b; Kim et al. 2000); therefore, no enhancement to the S^+ density or the $[\text{S II}]/\text{H}\alpha$ ratios is expected.

3.3. DEM L 106 (N30C)

DEM L 106 is an X-ray-dim superbubble; i.e., it has not been detected in long-exposure X-ray observations, and the 3σ upper limit of its X-ray luminosity does not exceed that expected by Weaver et al.’s (1977) bubble models (Chu et al. 1995). The expansion velocity of DEM L 106 is $\sim 10 \text{ km s}^{-1}$ (Shaw, Chu, & Gruendl 2000). This superbubble contains the OB

association LH38 (Lucke & Hodge 1970); its stellar content has been studied in detail by Oey (1996a).

Our WFPC2 $H\alpha$ image covers the shell’s center and southern rim. The morphology of the shell is amorphous with embedded dusty features. The lack of sharp filaments is consistent with the small expansion velocity. At the northern part of the field, in the WF2 CCD, are the B[e] star S22 and two compact H II regions. The H II regions are surrounded by a bow-shock-like structure pointing toward S22, suggesting a possible dynamic interaction. This interaction will be reported by Shaw et al. (2000).

3.4. Optical Morphology and X-ray Surface Brightness

The main purpose for obtaining HST WFPC2 images of the superbubbles DEM L 152, DEM L 192, and DEM L 106 is to search for small, sharp, filamentary, [S II]-enhanced features that are directly associated with SNR shocks, such as those observed in the SNR N63A (Chu et al. 1999). However, these images do not detect any sharp features with [S II]/ $H\alpha$ ratios reaching the canonical value for SNRs, ≥ 0.7 . The absence of detectable SNR-shocked material indicates that SNRs are not interacting with any high-density material, such as dense cloudlets or the cold dense superbubble shell. This result supports the previous suggestion that the interior SNRs have interacted with only the hot, lower-density gas in the superbubbles.

The WFPC2 images show different overall morphologies in the three superbubbles, with DEM L 152 being the most filamentary and DEM L 106 the least. The filamentary morphology of a superbubble is produced by the post-shock compression as the superbubble expands into the ambient interstellar medium. It is thus expected that superbubbles with higher expansion velocities should show more filamentary morphologies.

It has been noted that X-ray-bright superbubbles have higher expansion velocities than expected in models taking into account realistic stellar wind energy input (Oey 1996b). Our WFPC2 images illustrate that the superbubble shell morphologies are caused by the

interstellar shocks associated with the superbubbles’ outward expansion, instead of being caused by direct interaction with SNRs. There is no morphological or kinematic evidence that interior SNRs in the X-ray-bright superbubbles DEM L 152 and DEM L 192 shock the cold shells directly (this paper; Magnier et al. 1996; Kim et al. 1998a). The expanding shells of X-ray-bright superbubbles must have been accelerated indirectly.

We suggest that the SNRs in superbubble interiors only shock-heat the interior gas, raising the pressure of the superbubble interior. The superbubble expansion, driven by an increased pressure, accelerates. The resultant higher expansion velocities lead to stronger outer interstellar shocks, which produce filamentary shell morphologies. In this picture, filamentary shell morphologies should be associated with high X-ray surface brightness of superbubbles.

It is of interest to see whether or not this correlation between nebular morphology and X-ray emission is valid in general for a large sample of objects. The *HST* archive of WFPC2 $H\alpha$ images and the *ROSAT* archive of X-ray observations of the LMC fields provide excellent data sets for us to examine the relationship between nebular morphology and X-ray emission. We have found in the *HST* WFPC2 archive (up to 1999 November) $H\alpha$ images for ~ 50 fields in the LMC. Among these $H\alpha$ images, filamentary morphologies comparable to that of DEM L 152 (N44) are found only in the superbubble N103 around the double cluster NGC 1850 (Gilmozzi et al. 1994). Figure 3a shows a WFPC2 $H\alpha$ image of the cluster NGC 1850 and a portion of the superbubble N103.

We have further examined archival *ROSAT* Position Sensitive Proportional Counter observations of N103 (Chu et al. 1999). As shown in Figures 3b and c, N103 is projected near three other X-ray sources: (1) the bright SNR 0509-68.7 (N103B) outside the northeast rim of the superbubble; (2) a point X-ray source at $5^{\text{h}}07^{\text{m}}36^{\text{s}}$, $-68^{\circ}47'52''$ (J2000), coincident with the cluster HS122 (Hodge & Sexton 1966) projected at the southwest rim of N103; and (3) a large faint ring of diffuse X-ray emission originating from a probable foreground SNR in the halo of the LMC (Chu et al. 1999). On the same line of sight, a fourth component of X-ray emission is present within the superbubble N103. The spatial correspondence between this

X-ray emission and the $H\alpha$ emission suggests a physical association. Therefore, N103 provides another supporting case for the correlation between filamentary superbubble morphology and diffuse X-ray emission.

The existence of a SNR in the interior of N103 has been suggested by Ambrocio-Cruz et al. (1997) based on the kinematics of the superbubble; they find an expansion velocity of 57 km s^{-1} . The large expansion velocity is probably due to the acceleration of material by the pressure increase induced by the SNR shock and must be responsible for the filamentary shell morphology. These properties are very similar to those of the X-ray-bright superbubble DEM L 152 (N44).

4. Summary and Conclusions

We have presented *HST* WFPC2 images of three LMC superbubbles: DEM L 152, DEM L 192, and DEM L 106. From these images and all archival *HST* WFPC2 images of ionized gas in the LMC, we find that the filamentary morphologies of superbubbles are usually associated with large expansion velocities and interior X-ray emission. This correlation may be understood in terms of interior SNRs near the superbubble shell walls. SNRs interacting with the inner walls of a superbubble may shock-heat and pressurize the superbubble interior to produce bright X-ray emission and to accelerate the shell expansion. Filamentary shell morphologies are produced by strong interstellar shocks associated with fast expansion.

We also find that the $[S II]/H\alpha$ ratios of superbubbles are dependent on the stellar UV radiation field as well as the interstellar shocks resultant from the superbubble expansion. Comparisons between the superbubbles DEM L 152 and DEM L 192 show that high $[S II]/H\alpha$ ratios are produced only if the ionization front is trapped in the superbubble shell. This conclusion differs from Oey’s (1996b) suggestion that high $[S II]/H\alpha$ ratios are correlated with large expansion velocities and high X-ray surface brightness of superbubbles. The stellar UV radiation field must be taken into account in the interpretation of $[S II]/H\alpha$ ratios of

superbubbles.

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FIGURE CAPTIONS

Fig. 1.— *HST* WFPC2 $H\alpha$ images of (a) DEM L 152, (b) DEM L 192, and (c) DEM L 106. The insets are wide-field $H\alpha$ images taken with the CTIO Curtis Schmidt telescope; the field of view is $10' \times 10'$. The WFPC2 field of view is outlined in the inset.

Fig. 2.— $[SII]/H\alpha$ ratio maps of N44 and N51D determined from *HST* WFPC2 images.

Fig. 3.— (a) *HST* WFPC2 image of the superbubble N103 around the double cluster NGC 1850. The inset is a wide-field $H\alpha$ image taken with the CTIO Curtis Schmidt telescope; the field of view is $10' \times 10'$. The WFPC2 field-of-view is outlined in the inset. (b) *ROSAT* PSPC X-ray image of N103 in the 0.5–2.0 keV band, produced from the observations RP300129N00 and RP500037N00. The image has been smoothed by an adaptive-filter with a kernel of 50 counts, which is equivalent to a smoothing area of a radius of $\sim 1'$. (c) *ROSAT* PSPC X-ray contours over a CTIO Curtis Schmidt $H\alpha$ image of N103. The contour levels are 0.001, 0.0015, 0.002, 0.0025, 0.005, 0.0075, and 0.01 counts $s^{-1} \text{ arcmin}^{-2}$.

Table 1: Journal of *HST* WFPC2 Observations

Object Name	R.A. ^a (J2000)	Decl. ^a (J2000)	$\lambda_c/\Delta\lambda$ (Å)	Exposure (s)	Notes	Date of Obs
DEML 152 (N44)	$5^h22^m38^s.5$	$-67^\circ57'47''$	6563.7/21.4	2×500	H α	1999/1/17
			6732.1/47.2	2×600	[S II]	1999/1/17
DEML 192 (N51D)	$5^h26^m15^s.2$	$-67^\circ29'58''$	6563.7/21.4	2×500	H α	1998/11/16
			6732.1/47.2	2×600	[S II]	1998/11/16
DEML 106 (N30C)	$5^h13^m41^s.2$	$-67^\circ27'35''$	6563.7/21.4	3×800	H α	1998/11/14

^aThe right ascension and declination of each object refers to the center of Planetary Camera (PC1 chip)

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